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'VISUAL ADAPTATION' AMONG LEPIDOPTERA: OBSERVATIONS AND EXPERIMENTS BY F. SÜFFERT

By V. B. WIGGLESWORTH, M.D., F.R.S., F.R.E.S.

DURING a visit to Berlin in the early part of this year I had opportunities for many discussions with Professor F. Süffert, who is one of the few people in Germany who are intensely interested in and have made a scientific study of those questions of form and coloration in Lepidoptera that we in this country have learned to regard as the special province of Sir Edward Poulton and his school. It occurred to me that it might be of interest to the Society if I were to review a few of Süffert's observations as published in German [1] a few years ago.

In recent times a good deal of scepticism has been expressed by academic zoologists not only with regard to the belief that the evolution of protective coloration among insects is the result of natural selection, but of the very existence of "protective coloration"—using this term in its widest sense. Süffert has therefore attempted to put the entire subject on a firmer basis by describing and analysing a number of examples in great detail and sifting out the general principles that are common to all of them. All these related phenomena he embraces under the non-committal term of "visual adaptations"—that is, modifications of form, coloration and behaviour which must owe any ecological value they possess to the visual impressions they exert upon other animals. In the work I am going to speak about he deals solely with what we should call cryptic coloration in the larvae and pupae of Lepidoptera; and almost exclusively with examples of "countershading"—that is, the elimination of apparent roundness by the provision of pale areas in those regions where the shadows mostly fall; the principle demonstrated by Thayer in many groups of animals.

This principle was first recognised among Lepidoptera by Sir Edward Poulton and, as might be expected, it is to be found described in those rich mines of information, "Notes upon lepidopterous larvae 1886 and 1887." Two examples are there given: firstly the apparent elimination of the furrow where the larva of *Rumia crataegata* (L.) holds on to a stem, by the pale pink colouring of the fleshy protuberances on which the shadow falls; and secondly the apparent flatness of the pupa of *Apatura iris* (L.) induced by an increasing whiteness of the pupal shell in those regions that are most deeply in the shade.

Two main types of countershading of this kind are recognised by Süffert among Lepidoptera. In the first type there is a single system: the body is darkest on the side where the light comes from and palest in the most heavily shaded regions, so that a single uniformly illuminated and therefore apparently flat surface is produced. In the second type a longitudinal pale line or "line of contrast" separates two regions which are countershaded independently, so that when illuminated in the normal manner two apparently flat surfaces of different tones, separated by a pale line, are produced.

Many examples of these types of countershading are described in detail. The larva and pupa of *Colias edusa* (Fabr.) provide the standard example of the

[1] 1932, *Z. Morph. Oekol. Tiere* **26**: 147–316.

two-surface effect. The larva is most deeply coloured dorsally, becoming paler towards the lateral line; below the lateral line it is dark above, becoming paler ventrally. When light falls on the larva from above, this gradation is counteracted by the intensity of the shadow and the two surfaces appear of uniform tone and therefore flat. In the pupa the same effect is seen; but it is effective only when the light falls on the ventral surface.

Larvae and pupae of *Apatura iris* and *A. ilia* (Schiff.) provide examples of the single-surface effect. But here countershading is in the long axis of the body. The larva rests on the leaf normally with the head uppermost; it is most deeply coloured anteriorly and thus appears flat when illuminated from in front. In the pupa the conditions are reversed: it hangs head downwards, it receives the light therefore from its posterior end and, correspondingly, is most deeply shaded at this extremity.

There are many other examples of the same kind; the larva of *Actias selene* Hübn. is a particularly striking one. The line separating the two surfaces is usually longitudinal; sometimes, as in the pupa of *Libythea celtis* Laich., it is oblique. In pupae it is always made up of a number of elements, unrelated anatomically, which come to form a continuous line only when the development of the pupal shell is completed. That is a further piece of evidence that the significance of this line lies in the visual effects it produces. All these visual effects are absent from pupae developing in concealed situations.

Now all these countershading effects can be realised only when the light falls on the insect from a given angle.[2] And one of the most important parts of Süffert's work consists in the demonstration that not only do the insects in fact take up the appropriate attitudes in relation to the light in nature but that they do so, sometimes in response to gravity, but often in response to the stimulus of the light itself. For example, larvae of *Colias edusa* which normally rest on the upper surface of the stems, will rest on the lower surface if the light is thrown upwards by means of a mirror.

Finally a series of experiments was carried out with the larva of *Gonepteryx rhamni* (L.) in order to find out where the sense organs reside which bring about this orientation towards the light. This larva normally rests with the light falling upon its back. If it is illuminated from one side, it twists its body round in that direction. It was shown that if the body is shaded during this experiment and only the head is illuminated, the caterpillar will incline towards the light to a very small extent only; whereas this inclination is far more pronounced if the head is shaded and the body alone is exposed. Clearly the insect can respond to light perceived by receptors in the general body surface; and it is therefore highly probable that not only this inclination towards the light but also the assumption of the normal resting attitude, involving as it does the selection of a suitable resting site, is brought about through these same dermal sense organs of light perception.

[2] The larvae and pupae of Lepidoptera differ in this respect from the chamaeleon. As Sir Edward Poulton told me in a letter, when he was in South Africa many years ago with Dr. Longstaff and Sir Charles Boys, he discovered that the chamaeleon can produce at will darkening on the side turned to the light and brightening on the side in shadow.

DIMORPHISM IN THE MALES OF COLEOPTERA

By Gilbert J. Arrow, F.R.E.S.
(*British Museum* (*Natural History*).)

In 1928 (*Trans. ent. Soc. Lond.* **76** : 73) I recorded certain cases of the occurrence of two distinct forms of male in horned beetles (Copridae and Dynastidae) and in a later paper (1937, *Trans. R. ent. Soc. Lond.* **86** : 239) I discussed the phenomenon in Stag-beetles (Lucanidae), the mandibles of which show the same liability to assume two different and unconnected phases as the horns in the two other groups. Yet another group can be added, much less nearly related to the three families above mentioned than these are to one another. In the Cerambycidae dimorphism of the male occurs in the mandibles precisely as in the Stag-beetles. As in the latter, the males of many of the largest forms of Cerambycidae show a great enlargement of the mandibles, its degree depending upon the size of the individual. In the females the jaws are sharp-edged scissor-like instruments, evidently well adapted for cutting and gripping, the left one, as seems to be the rule, passing over the right. The cutting edges have projections which alternate more or less on the right and left sides and the tips cross one another and are very acute. The South African *Cacosceles newmanni* may be taken as an example. In small males of this the mandibles are almost the same as in the females, although the blades are rather less broad and fit less closely. Larger males have progressively longer and narrower mandibles, which become curved and lose contact except at the tips, the projections of the inner edge disappear and a calliper-shape is produced. The left mandible, however, is always forked at the tip and the right one simple.

In the related Indian *Priotyrannus mordax* small males have also toothed scissor-like mandibles, almost identical with those of the female, and large males untoothed calliper-shaped organs of very different form; but here no transition from one to the other is found. Alteration of shape from small to large specimens is slight and the change from one phase to the other quite abrupt. Of 21 males in the British Museum, 11 belong to the ordinary variable form and 10, all of the largest size, to the isolated, calliper-jawed phase. In the latter both mandibles are forked at the end. It may be safely predicted that no transition between the two forms of male will be found to exist.

In my paper on dimorphic Stag-beetles mentioned above I described and figured two cases in which the mandibles characteristic of the two phases were found in the same specimen. M. Oberthur informs me that he has found in his collection an exactly similar male example combining the two phases of *Dorcus suturalis* Westw. which I figured and described in that paper (p. 240, pl. 3, figs. 1 and 2). Since writing the paper I have read the notes published by A. M. Lea in 1909 and by P. Nagel in 1922 on the splendid Australian Stag-beetle, *Lamprima latreillei* McL., in both of which a specimen with similarly abnormal mandibles is represented. A third example is mentioned by Lea. In all three the right mandible is of the type formerly believed to indicate another genus (*Neolamprima*). Mr. H. Hacker, who collected over 80 specimens, of which those mentioned by Lea formed part, is quoted by the latter as having written : "There seem to be three well-defined forms of mandible, long, medium and short, rather more than a gradual merging from long to short."

The British Museum collection of 39 males consists of 34 specimens of the *Lamprima* phase with unidentate mandibles, their body-length varying from 14 to 28 mm., and 5 of the *Neolamprima* phase with pluridentate mandibles, whose body-length is from 22 to 25 mm. only. Lea's measurements of his examples show a body-length of 17 to 26 mm. for unidentate specimens and 19½ to 28 mm. for pluridentate. This shows that there is no regular progression in the development of the mandibles according to the size of the individual. Specimens with single-toothed mandibles have the full range of size attained by the species and those with pluridentate mandibles form a parallel series with a smaller range of size which includes no small specimens. The species is therefore also dimorphic in the male and the abnormal specimens represented by Lea and Nagel show in their right and left mandibles respectively the distinctive features of the two phases. The pluridentate phase is less constant than the corresponding form in *Calcodes siva* Hope, *C. carinatus* (L.), and other species described by me, and in that respect *Lamprima latreillei* resembles the African *Dorcus faber* Thoms. The term " isolated phase " may be used in preference to " constant phase," which I employed in 1937, the most notable feature being the absence of intermediates linking this phase with the primitive one.

In the New Guinea species, *Lamprima adolphinae* Gest., which is very closely related to *L. latreillei*, the two types of mandible also occur, but the isolated phase is the predominant one. In a series of 46 males in the British Museum, whose body-length ranges from 17 to 37 mm., the smallest specimen only has unidentate mandibles. It seems likely that, as I have suggested may be the case with *Dorcus faber*, the primitive phase is in course of disappearance.

It is noteworthy that the most familiar species of *Lamprima*, *L. aurata* (Latr.), which is very abundant in south-eastern Australia, and is so closely related to *L. latreillei* that they can only be distinguished with a little difficulty, seems to have only unidentate mandibles. It would be no cause for surprise if, under favouring conditions, whatever they may be, a pluridentate form made its appearance.

These wonderfully brilliant insects seem to display themselves in great numbers and it may be supposed that they are protected by unpalatability against insectivorous birds, etc. Their colours are extremely varied, but there seems to be a tendency for the individuals of a colony to be of the same colour. A long series of *L. adolphinae* taken by Pratt, probably all at the same time, are of a uniform golden-red colour ; another series collected by Meek at Collingwood Bay are almost black and the specimen with unidentate mandibles mentioned above is one of many from Komba, Finistere Range, to which Nagel has given a varietal name, *olivacea*. No purpose seems to me to be served by naming colour-phases which, in a sufficiently long series, would show every gradation.

Nagel (1930, *Stettin. ent. Ztg* **91** : 87) describes *Lamprima latreillei* as the most widely distributed species of the genus, ranging from Victoria to north Queensland, but I have been able to find specimens only from Queensland. It seems to abound chiefly in north Queensland and I believe the isolated male phase has only been recorded from that region. From New South Wales and Victoria I have seen only *L. aurata* (Latr.), in which the metasternal process is not produced. I am inclined to doubt whether *L. varians* Burm. (South Australia) should be considered more than a local race of that species.

ON THE STRUCTURE AND FUNCTION OF THE HIND SPIRACLES OF THE LARVA OF THE BEETLE *DONACIA* (COLEOPTERA, CHRYSOMELIDAE)

By G. C. Varley, M.A., Ph.D., F.R.E.S.

The early stages of a number of different insects live in mud and obtain their supply of oxygen by piercing the roots of plants with their specially modified spiracles. In a previous paper (Varley, 1937) it was shown that the sharp piercing spiracles of the larvae of the flies *Chrysogaster* (Syrphidae) and *Notiphila* (Ephydridae) have openings close to their tips so that by piercing a root a larva at once puts its tracheal system in direct connection with the gas in the intercellular spaces in the root, which, as Ege (1915) has shown, may contain up to 12% of oxygen. The larvae of the Chrysomelid beetle *Donacia semicuprea* Pz. live side by side with these fly larvae, and they also pierce the roots with their strong hook-like hind spiracles. It seemed curious then that in the most recent detailed account of the spiracles of *Donacia* (Böving, 1910) it was concluded that the functional spiracular openings were not in such a position that they could be inserted into the roots, but were at the very base of the hooks. The opinion was therefore expressed (Varley, 1937) that certain apparent slits in the hooks, which were considered by Böving to be covered over by thin membranes, might be the true spiracular openings, and enable the spiracles to function in the same way as do those of the fly larvae already mentioned. Ege (1915) makes the same suggestion. In 1938 I had the great pleasure of meeting Dr. Böving, and he encouraged me to re-investigate the structure and function of these specialised spiracles.

The larvae of *Donacia* (figs. 1, 5) were first described by Kunze (1818) and since then the structure of their spiracles has been studied by a long succession of workers, notable amongst whom are Schmidt-Schwedt (1887, 1889), Dewitz (1888), Sanderson (1900), MacGillivray (1903), Böving (1906, 1910) and Deibel (1910). That the peculiar spiracular hooks on the eighth abdominal segment are concerned with respiration has been generally agreed, and that the tips of the hooks are actually inserted into the roots of the plants on which the larvae feed was noted by von Siebold (1859) and confirmed by the careful observations of Schmidt-Schwedt (1887) and has not since been disputed. However, no two authors seem to have been in agreement as to the way in which the hooks function as spiracles, and there is considerable dispute as to the interpretation of their structure.

Most authors are agreed that in the fully grown larva each spiracular hook contains two pairs of air-filled chambers which are separate over the greater part of the length of the hooks, but whereas Schmidt-Schwedt (1889) and Deibel (1910) considered the upper and lower chambers to be separated incompletely from one another, MacGillivray (1903), Sanderson (1900) and Böving (1910) believed the partition between them to be complete, though Sanderson thought that the membrane between them might act as a gill. Deibel, Schmidt-Schwedt and Sanderson found that the upper paired chambers communicated with the outside by longitudinal slits, but MacGillivray and Böving thought that the apparent slits were covered over by thin membranes. Dewitz, MacGillivray,

Böving, and Deibel thought that the chambers of the hook were not in communication with the atrium of the spiracle, and only Schmidt-Schwedt claimed that the felty plug which separates the two cavities was freely permeable to air. This latter author, then, was alone in considering that the cavities within the hook provide a direct channel by which the larva can obtain oxygen from the plant roots. Sanderson, while admitting this as a possibility, preferred to believe that the channel is not open the whole way, but that a membrane which acts as a gill separates the upper from the lower chambers. The other authors all considered that the channel was blocked at one or more places, and therefore regarded an irregular hole at the base of the hook as the true functional aperture of the spiracle. This aperture was shown by Schmidt-Schwedt to be the stigmatic scar, since it is absent from the first instar larva.

It is perhaps surprising to find such diversity of opinion about anatomical details, but it must be remembered that the structures are themselves very minute, and not easy to see clearly even in thin sections. Much of the early work was done on whole mounts or hand-cut sections, which must have been difficult to study owing to their thickness. Schmidt-Schwedt (1889) was apparently the only author who tested his anatomical conclusions by experiment, but later workers seemed quite unconvinced by these and apparently made no attempt to confirm or refute them. In this paper a series of simple experiments is described, which confirm those of Schmidt-Schwedt, and the structure of both first and last instar larvae is re-described and illustrated.

Material and methods.

All the material was collected from a small backwater of the river Cam about a mile above Cambridge, by digging or pulling up the roots of the grass *Glyceria aquatica* Sm. and washing away the adherent mud through a coarse net. The numerous adult beetles found in cocoons on the roots all belong to the species *Donacia semicuprea* Pz. Eggs were found exactly as described by Böving (1910) in the leaf bases close to the water-line. They were kept in glass vials till they hatched.

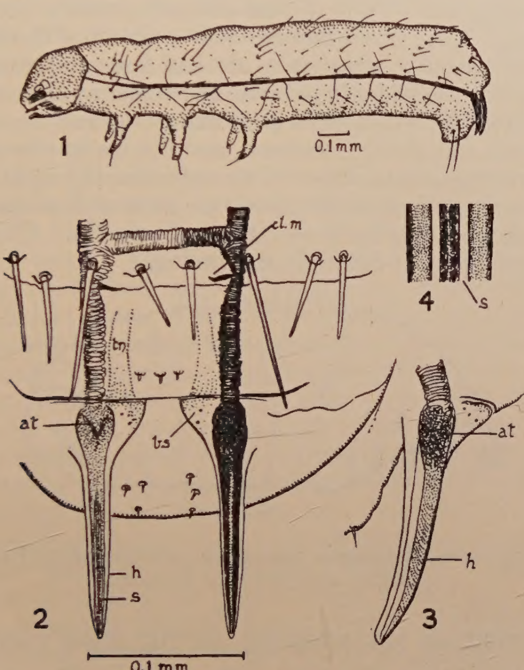
Microscopical preparations of the spiracles were made in various ways. Whole mounts, either fresh or boiled in potash, were made in Faure's fluid. For serial sections of the fully grown larva Petrunkewitsch's fixative was first tried, but it rendered the chitin too brittle; material simply fixed in alcohol, or gently boiled in potash, was much more satisfactory. Sections were stained in Delafield's haematoxylin. No chitin stains were used as the chitin of the hooks is naturally deeply pigmented.

The function of the hind spiracles of the fully grown larva.

The main point at issue is whether there is a free passage for air through the spiracular hooks from the tip via the chambers in the body of the hooks through the atrium to the tracheae. Tests were made first with paraffin oil stained in Sudan III, which effectively enters the tracheal system of most insects. The cuticle of *Donacia* is covered with a layer of hydrophil scurf, which, on wetting with oil, can be flaked off, leaving the cuticle shiny, white, and strongly hydrofuge. In the following experiments the larvae were dried on blotting-paper, and rubbed over with a very small amount of olive oil; the scurf and the olive oil were then rubbed off on dry clean blotting-paper. Fig. 5 indicates that the fully grown larva of *Donacia* has a series of lateral spiracles. These were shown to be open by covering the hind spiracles of a larva with gelatin, and immersing

it in coloured paraffin oil. Oil rapidly entered the tracheal system, where it was visible through the transparent body wall in the large tracheal trunks. The fact that these lateral spiracles are open had to be taken into account in the following experiments.

Experiment 1. Two larvae were cleaned with olive oil and covered with a thin layer of durofix in such a way that the only parts of the body remaining uncovered were the tips of the spiracular hooks. The lateral spiracles and the stigmatic scars at the bases of the hooks were covered over. Oil was applied to the hooks on a tiny wad of cotton wool, and on dissection of the larvae coloured oil was found in the main tracheal trunks. This suggests that the oil entered through the spiracular hooks, but it does not entirely rule out the possibility that the oil might penetrate beneath the layer of durofix and enter the lateral spiracles of the stigmatic scar. More direct evidence was obtained in the following way :



FIGS. 1–4.—1. First instar larva of *Donacia semicuprea*, showing the tracheal system; 2. hind spiracles of first instar larva in postero-dorsal aspect, drawn from a specimen compressed dorso-ventrally; 3. hind spiracle of first instar larva in lateral aspect; 4. detail of posterior aspect of part of the spiracular hook, showing the spiracular slit.

Experiment 2. Larvae were placed in coloured oil until the air in the tracheal system was largely replaced by oil, and, after washing quickly in clean oil, the larvae were placed between two glass slides separated by plasticene and watched under the microscope. On compression coloured oil was expressed from the larvae, and appeared from the spiracular hook, and not from the region of the stigmatic scar.

Experiment 3. Live larvae were placed in water in the compressorium

and bubbles of air were squeezed out of them. As the pressure was slowly increased a bubble appeared suddenly on the posterior surface of one hook, at about its middle. Usually the bubble was taken back into the body on reduction of the pressure. No bubbles ever came from the stigmatic scar. This experiment is a repetition of one of a series performed by Schmidt-Schwedt (1889) and the results are identical with his. It might be objected that these experiments, which rely on considerable lateral pressure on the larvae, cause injury to the spiracles. This is unlikely because during compression the hooks do not touch the glass slides and Schmidt-Schwedt in one of his experiments used warming instead of compression of the larva, and again obtained the same result. It might also be objected that if, as Böving supposed, the spiracular slits are covered over with thin membranes, these might be ruptured by the pressure. Experiment 1 is not open to this objection, and in experiment 3 the pressure needed to expel the oil is very slight. These experiments between them indicate that there is an open channel within the hook which is permeable to air and to paraffin oil. They do not indicate exactly the position of the spiracular aperture. That this in fact extends to the tip of the hook is proved by the following observation: after some air had been expressed from a larva the pressure upon it was suddenly reduced and water at once entered the lower chambers of the spiracle, which were kept under observation under the microscope. The pressure was slowly increased, and the water was driven out again, and the concave meniscus was observed to move steadily right to the tip of the hook. Successive repetitions of the procedure showed that the water was flowing out freely from the slit in the hook right up to the tip. This is in agreement with the findings of Schmidt-Schwedt and Deibel.

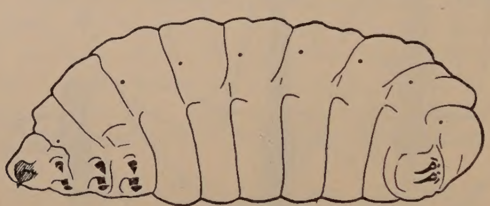


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Fig. 5.—Fully grown larva of *Donacia semicuprea* in latero-ventral aspect, showing the lateral and posterior spiracles.

The structure of the spiracles of the first instar larva.

The newly hatched larva (fig. 1) is metapneustic. The paired longitudinal trunks are joined posteriorly by a commissure, posterior to which is the closing mechanism of the hind spiracles (*see* Böving (1910), and Deibel (1910)). These are slender spine-like hooks 0·15 mm. long (figs. 2, 3) and their basal sclerites articulate with the body, allowing them to move in a vertical longitudinal plane. A tendon is attached to the anterior border of the basal sclerite, and a small group of two or three campaniform sensillae is situated on the latter close to the line of articulation. These are probably proprioceptive sense organs of the type described by Pringle (1937) in the joints of the cockroach.

In fresh mounts when the tracheal system is filled with air (right-hand side of fig. 2) it can be seen that each trachea leads to a slightly expanded atrium which lies beneath the basal sclerite; from this two air-filled chambers extend to the tip of the spiracular hook, running along its posterior convex

edge, where they appear to open by longitudinal slits. The appearance of these slits under oil immersion is indicated in fig. 4, where they are separated by a wall which seems to be made up of a double row of small pillars. These do not show at all clearly in lateral view.

Examination of the spiracles of the first instar larva confirms the observation of Schmidt-Schwedt that there is no aperture of any kind at the base of the spiracular hook, and suggests that there is a direct passage for air from the paired slits in the hooks through the chambers to the atrium and thence into the tracheae.

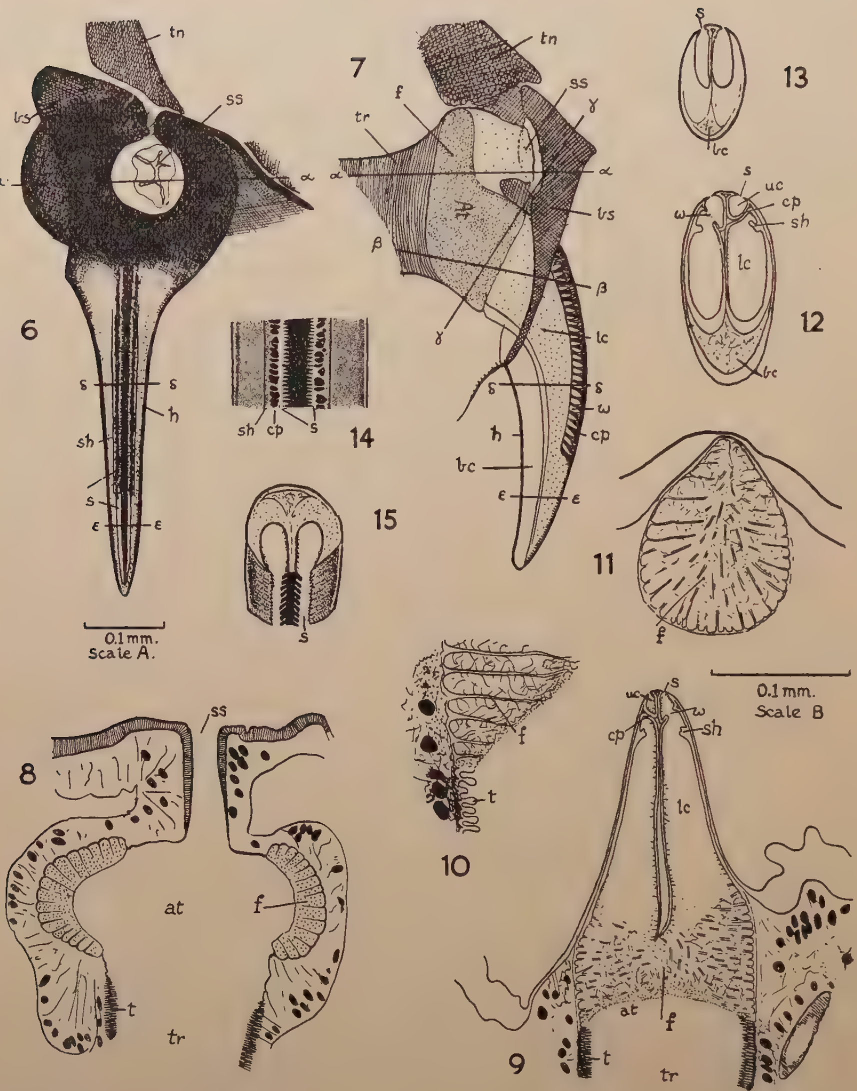
The structure of the hind spiracles of the mature larva.

The larva is now peripneustic, but the lateral spiracles are simple structures, and apparently have no function in the life of the larva. The two hind spiracles lie close together at the posterior end of the larva (fig. 5). Viewed from behind, each is a sharp slightly curved spine or hook (fig. 6) arising from a pigmented basal sclerite (bs) in the centre of which is the spigmatic scar (ss). Dorsally the basal sclerite articulates with a small sclerite (tn), from which arises an invaginated tendon-like apophysis to which are attached the levator and depressor muscles of the hooks. On the basal sclerite, close to its articulation with the tendon, is the group of campaniform sensillae, whose number has now increased to about eight.

The relationship of the trachea and the atrium to the basal sclerite and the stigmatic scar can be seen in fig. 7, which is a semi-diagrammatic representation of a spiracle which had been boiled in potash, seen in lateral aspect, as from slightly within the body. Figs. 8 and 9, which are drawings of sections along the lines $\alpha\alpha$ and $\beta\beta$ of fig. 7, show that the trachea leads into a wide atrium the walls of which are thick and felty. From the dorsal side of the atrium a narrow tube leads to the stigmatic scar, which in sections fixed in alcohol appears to be open. No doubt it was this appearance which led previous authors to think that this was the true stigmatic opening. In living specimens, however, the scar appears as a groove or slit, the edges of which are firmly pressed together, in the middle of a slightly tumid area of soft colourless cuticle. There is no evidence at all from the experiments that air or oil could be forced out of this slit.

From the ventral side of the atrium arise two outgrowths (figs. 7, 9; 1c) which pass into the hook and occupy most of its cavity. The felty atrial walls are here so thick that they meet together and form a complete but porous partition between the atrium and the chambers of the hook. This is illustrated in fig. 11, which is a section along the line $\gamma\gamma$ of fig. 7. This felt looks remarkably solid in thick sections, and was thought by various authors to be impermeable. Examination under oil immersion shows beyond doubt that it is formed from a dense mass of plumose chitinous filaments (figs. 10, 11; f). Fig. 10 might give the impression that the filaments were plates. That this is not so is seen in figs. 9 and 11, where the filaments do not run in the plane of the section. It is also confirmed by the examination of the walls of the atrium in whole mounts, where the base of each filament is clearly seen as a refringent spot.

The detailed structure of the hook is complex. In whole mounts its posterior surface shows a series of light and dark longitudinal bands (figs. 6, 14, 15). These are most complex in the middle of the hook, near the line $\delta\delta$, which is shown in section in fig. 12. The hook here contains five main chambers; paired upper and lower chambers filled with air, and a single basal chamber, which in life contains no gas and is probably filled with a fluid which is either blood or serum. The two lower chambers are separated from one another by a



FIGS. 6–15.—The structure of the spiracles of the last instar larva of *Donacia semicuprea*; 6. right hind spiracle in posterior aspect; 7. hind spiracle, boiled in potash, seen in antero-lateral aspect, so that the basal sclerite is seen from within; 8. section of the spiracle through the stigmatic scar (line αα in figs. 6 and 7); 9. section through the base of the hook, along the line ββ of fig. 7; 10. detail of structure of the felt of the atrial chamber, taken from a section close to that illustrated in fig. 9; 11. transverse section through the felty plug which separates the atrial chamber from the chambers of the hook. The section is along the line γγ of fig. 7; 12. transverse section of the spiracular hook along the line δδ of fig. 7; 13. transverse section of the spiracular hook along the line εε of fig. 7; 14. detail of the posterior aspect of the hook in the region shown in section in fig. 7; 15. detail of the posterior aspect of the hook close to the tip, in the region shown in section in fig. 13. Figs. 6–7 are drawn to scale A, 8–9, 11–13 to scale B, and 10, 14–15 are still further magnified.

double wall (figs. 9, 12), and the outer wall of each has an inwardly projecting chitinous shelf. The upper chambers are much smaller, and open to the outside by narrow slits which extend to the tip of the hook. Each is separated from the lower chamber of its side by a fenestrated partition made up of chitinous pillars, between which are lancet-shaped windows (fig. 14). Sanderson regarded these pillars as hollow tubes, and thought that they might function as gills. This seems to be very unlikely, as in live larvae the upper chambers are not filled with water but with air. The chitinous shelf appears in whole mounts as a refringent line, which might easily be mistaken for a slit-like opening, were it not for the evidence of the sections. In posterior aspect (fig. 14) the chitinous pillars appear as a series of irregular dark objects, and in whole mounts the spiracular slits in this region of the hook are very difficult to detect between them and the middle dark band. The fenestrated partition is entirely absent from the apical part of the hook (figs. 7, 13) where the upper and lower chambers of the hook become confluent, so that the structure in this part of the hook resembles that of the hook in the first instar. In this part of the hook the chambers open by obvious slits 0·005 mm. wide, which extend to the very end of the hook. Between the slits is the central wall the toothed processes of which form the inner margins of the spiracular slits (fig. 15). Air entering these slits from the intercellular air spaces of the root can pass into the upper and lower chambers of the hooks, and from there pass through the felt plug into the atrium, and thence into the tracheae.

The morphology of the spiracular hook.

The complexity of the structure of the spiracles in this group of beetles raises the interesting question of the morphological nature of the parts of which they are made, and of the way they develop. This problem cannot be solved by the study of the complete structure alone, but the evidence obtained from this goes some way to clarify the problem. The views expressed here are mainly in agreement with those of Böving, who considered this question in some detail, except that his view as to the closed nature of the spiracular hook is not accepted.

The side walls of the spiracular chambers are clearly double, as is the central wall separating them. In fig. 9 it can be seen that the outer lamella of the outer wall of the hook is continuous with the general body integument, and it must therefore have been formed as an evagination of the body surface; the inner lamella and the lamella of the central wall are continuous with the walls of the atrium, and are therefore to be regarded as atrial outgrowths. In the fully grown larvae the chambers of the spiracle are partly subdivided into upper and lower chambers, and it is not easy to see how this has come about. Possibly the chitinous pillars which form the fenestrated partition are to be regarded as secondary outgrowths of the inner or outer wall of the chambers. They might be a special development of the much less stout chitinous filaments which form the felt of the atrial region, and which spread a short way into the chambers. Probably the study of the spiracles of the intermediate instars would help to decide this.

In any spiracles which develop by the side of, and not around, those of the previous instar, the spiracular apertures must be formed anew in each instar by the breakdown of the body hypodermis and the hypodermal layer of the atrial chambers, so that a passage is made from the atrial chambers to the outside. In the fully developed spiracles there is no trace of a hypodermal layer in the

hooks at all. Since both the inner and outer lamellae of the walls of the hook must have been formed by hypodermal cells lying between them, what has become of these cells? MacGillivray's assertion that both the upper and lower chambers contained hypodermal cells is not in agreement with the interpretation advanced here and seems to be quite untenable. These cavities are regarded as being morphologically outside the animal, and could never have been lined within by cells. However, even in the basal chamber of the hook, which according to the present interpretation must have been lined with hypodermis, there is no trace of cells. The hypodermal epithelium has apparently shrunken away from the hook and left a space between itself and the cuticle which is filled with fluid. In all but the last instar larva this is a preliminary to the formation of the new spiracle underneath the old, as shown by Böving (1910). The formation of the new spiracle is probably similar to the formation of pupal structures from the so-called imaginal buds in holometabolous insects. It is hoped at a later date that it may be possible to investigate this in detail.

Summary and conclusions.

The experiments performed on the mature larvae of *Donacia* and the study of the structure of the first and last instar spiracles both lead independently to the conclusion that the spiracular hooks of *Donacia* are well adapted to pierce the roots of aquatic plants, and that there is an unobstructed channel through which gas can pass from the intercellular spaces of the plant root to the tracheal system of the insect, since the spiracular apertures are situated along the length of the piercing organs, and extend to their tips. The function of these spiracles is therefore identical with those of the Syrphid fly *Chrysogaster* and the Ephydrid fly *Notiphila*, which were described in a previous paper, though the structure of the spiracles in each case is quite different.

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Abbreviations used in the figures.

at, Atrium; *bc*, basal cavity; *bs*, basal sclerite; *c*, transparent cuticle; *cl.m*, closing mechanism of spiracle; *cp*, chitinous pillars; *f*, felt; *h*, spiracular hook; *lc*, lower chamber; *s*, spiracular slit; *sh*, shelf; *ss*, stigmatic scar; *t*, taenidia of the trachea; *tn*, tendon; *tr*, trachea; *uc*, upper chambers; *w*, windows of the fenestrated partition.

Book Notice.

Meadow and Pasture Insects. By Herbert Osborn, assisted by Mrs. D. J. Knull. pp. viii + 288. 8vo. Columbus, Ohio. (Educators' Press.) (1939.) Price $3.75.

This book is written by an author of wide practical experience in almost every State in the United States of America, and in Mexico and Canada.

It is written with special reference to American agriculture, but the ecological principles and the basis of control measures apply to farming practice throughout the world.

About one-third is devoted to a general discussion of basic principles and the remainder to a systematic treatment of the different orders of insects.

Chapters are given on meadow and pasture insects with a discussion of related forms; the ecology of the meadow; animal groups in the meadow fauna; the insect population; and general control measures for meadow and pasture insects.

The list of bibliographic references extends to 11 pages and the index to 4 pages of treble column.

Book Notice.

Catalogus Coleopterorum Daniae et Fennoscandiae auctoribus V. Hansen, W. Hellén, A. Jansson, Th. Munster, A. Strand. Curavit W. Hellén. 4vo. Helsingfors (Societas pro Fauna et Flora Fennica). 1939. pp. viii + 129, 1 map.

In 1896, C. Grill published a catalogue of the Coleoptera of Scandinavia, Denmark and Finland, which has been out of date for many years. In 1933 at the fourth congress of Northern Entomologists it was decided to produce a new catalogue, and this has been fulfilled.

The presentation is in tabular form with a column for each of the six districts of Denmark, Sweden, Norway, Finland and two adjoining Russian areas.

The countries are subdivided by the provision of smaller columns.

The systematic arrangement is that of Winkler's catalogue modified only by well-proven modern research. A short list of literature is appended, which is supplementary to that in the original catalogue by Grill.

Book Notice.

Principles of Forest Entomology. By S. A. Graham. 2nd edition. 8vo. London (McGraw-Hill). 1939. pp. xvi + 410, 165 figs. front. Price £1 4*s*.

The first edition of this work was published in 1929. It forms one of the McGraw-Hill Publications in the Zoological Sciences.

As in the first edition, the object of the work is to present forest entomology from the forestry viewpoint, and the emphasis is on the influence of insects on a forest rather than on the insects. Many new illustrations are added, most of them being original.

The introduction and historical review are succeeded by chapters on the Biotic potential, Environmental resistance, Insect Abundance, control by direct and indirect methods, the insects of the several parts of a tree, Insectivorous Parasites and Predators and other relations of forest insects.

A bibliography of 20 pages and a double-column index of 24 pages are provided.

THE EVOLUTION OF THE COPULATORY PROCESS IN THE ORDER ODONATA

By Lt.-Col. F. C. Fraser, I.M.S. Retd., F.R.E.S.

The genitalia of the female dragonfly is situated on the ventral surface of the 8th and 9th segments of the abdomen and in general does not differ from that of other insects of the same sex. That of the male consists of two sets of organs placed widely apart : one on the ventral surface of the 9th segment, which is the true penis and genital pore and corresponds to the same organ in other insects, and the other on the ventral surface of the 2nd and 3rd segments, which has no counterpart in other insects, or indeed in the whole Animal Kingdom.

The method of copulation has been adapted to this interposition of a secondary male organ, and is for the male first to transfer its sperm from the genital pore on the 9th segment to the secondary organ on the 2nd, after which the female copulates up with the latter and so consummates the act of coitus. There is no act of copulation between the primary genitalia of the male and that of the female; in this, the Odonata differ from all other orders of insects except Collembola.

No satisfactory explanation of this extraordinary method of copulation has ever been put forward, and, as Tillyard has remarked, its evolution is as complete a mystery as it well could be. This secondary organ on the 2nd segment is not homologous with any organ known in Zoology, and, moreover, is not developed from any pre-existing organ, save as a modification and amplification of the sternites of the 2nd and 3rd abdominal segments. Some authors have attempted to draw comparisons and even relationships with the Progoneate Myriapods, which have the genital pore situated far forward in the body, but this is sheer nonsense, since the true genital pore in the Odonata is situated far posterior, and the anteriorly situated organ on the 2nd segment has nothing to do with it, and is in fact an entirely new and unique structure.

In this paper I make no attempt to solve the problem of the evolution of the complicated apparatus on the 2nd segment, but I put forward suggestions as to the way in which the extraordinary method of copulation came into being. The organisation of the 2nd segment must have been subsequent to this and is of so intricate a nature that its evolution must have taken millions of years.

In starting this investigation, one fact stood out as a starting-point, viz., that both sexes had struck up a relationship with the 2nd abdominal segment of the male. If one supposes that the male had contracted the habit of masturbating on to the ventral surface of this segment, it still remains to be explained how the female became cognisant of the fact and made use of it. One explanation alone meets the case, and that is, that at the genesis of the act and its subsequent repetitions, the two sexes synchronised, or, in other words, at the time the act occurred the sexes were *in copulo*.

One is on safe ground in assuming that the method of copulation in the primitive Odonata did not differ from that employed generally by other insects. The situation of the male and female genitalia at the end of the abdomen is complete proof of this and the vestigial relics of the male penis on the 9th segment leave no doubt. Thus one may visualise the female curling up her

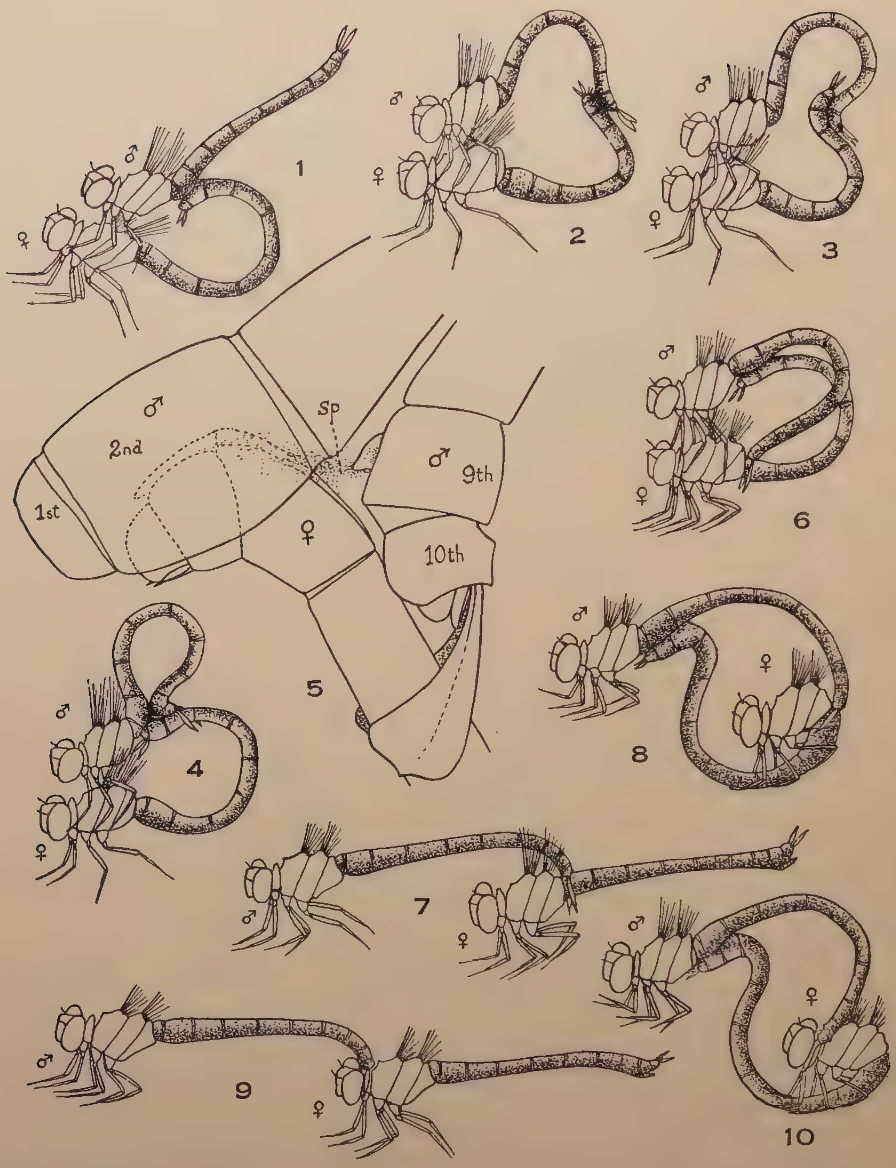

FIG. 1. The male dragonfly alighting on the female, which curls her abdomen upwards to facilitate coitus; 2 and 3. Copulation is effected; the ends of the two abdomens are pressed towards the 2nd segment of the male; 4. The genitalia of the two sexes are brought into close association with the 2nd segment of the male; 5. The female genitalia occupies the genital sac in the 2nd segment of the male to the partial exclusion of that of the male, which is seen to be discharging sperm into the sac. *Sp*, sperm; 6. The male shifts the grip of its anal appendages from the apical end to base of abdomen; 7. Tandem-flight follows with the male gripping the base of abdomen; 8. The female is now compelled to copulate by the ventral route instead of the dorsal; 9. The male shifts the grip of its anal appendages again, this time to a still more anterior position between the head and thorax; 10. The female copulates now in the modern way.

abdomen in strong dorsi-flexion to facilitate coitus as the male alights on her. Possibly the end of her abdomen curling upwards and forwards would come into contact with the ventral surface of the male's 2nd segment (fig. 1), or the efforts of the male in attempting coitus would press the female abdomen upwards and forwards towards this spot. When copulation had been completed, the two abdomens would enclose a cordate space with its apex directed thoracicwards and with its base strongly indented in the same direction (fig. 2). Continued invagination of this space would of itself ultimately bring the two genitalia into apposition with the 2nd abdominal segment of the male (figs. 3 and 4). In the course of many years, a definite association would be established between the genitalia and this segment and it is possible that the alternating rise and fall of the lateral walls of the tergites during respiration would assist in the invagination of the combined genitalia into the intertergital space. A gradual deepening of this shallow fossa, together with an expansion of the sides of the tergites, was most certainly a further stage in the development of the secondary genitalia. As the female genitalia sunk more and more deeply into the genital sac thus formed, there would be a strong tendency for the primitive copulatory process to be disturbed and finally the male organs would be quite unable to effect normal coitus with the female. *But at such a stage, the instinct to copulate at the site of the 2nd abdominal segment would have become strongly developed in the male,* and so, ineffective efforts to copulate with the female would still be made at this site (fig. 5). Failing success, the male would have to be content with discharging its sperm into the angle left between the 2nd segment and the female genitalia (figs. 4 and 5). I have little doubt in my own mind that such was the course of events, and suspect that this method of copulation persisted over many years before the male took to filling the genital sac prior to copulation with the female. It was probably during this time that the high state of specialisation of the secondary genitalia was arrived at, and the act of copulation, which had been of a semi-passive nature in so far as the male was concerned, now became an active one again with the formation of a second functional penile organ on the 2nd segment.

I propose now to consider the other actions which form part of the copulatory process and, on first consideration of these, their origin appears to be quite inexplicable. In the modern Odonata, prior to copulation, the male seizes the female by the prothorax or occiput, employing for this purpose the anal appendages situated at the end of the abdomen. I do not believe that this anterior site of seizure was the original one employed by dragonflies, but that it was attained by a gradual shifting of the clasp of the appendages from the end of the abdomen to a forward position, for it seems obvious that in the primitive method of copulation described above, the end of the abdomen would not have been free to seize the female in such an anterior position as the prothorax or head. Referring to figs. 4 and 5, it will be seen that I have shown the anal appendages grasping the end of the female abdomen, and if one considers the precarious hold that the male genitalia has, it will be evident that some such grasping organs would not only be very useful but vitally necessary. I think, therefore, that at that early stage of evolution, the anal appendages were already in an advanced state of specialisation; the elaborate organs to be found in the dragonfly of to-day are merely advances on the simpler and more primitive ones, to fit them for the new localities in the more anterior positions at the prothorax and head. The reasons for which these anterior positions were assumed, I think, may be answered as follows: Although the male had been gradually and then finally excluded from normal copulation, the instinct to

copulate still remained and when it found that ingress at the 2nd segment was denied it, it proceeded to grope round for some other spot where it could gratify this instinct. A reference to fig. 4 will show that the most convenient place within its reach was the base of the female abdomen or the recess between it and the thorax; to this spot, therefore, it altered its grip (fig. 6). It would have been impossible at this stage for it to grip the prothorax of the female, since its own legs and the wings of the female were in the way. *Tandem-flight with the male gripping the female by the base of the abdomen must have followed* (fig. 7), otherwise it is impossible to explain how the grip of the appendages came to be shifted from the abdomen to the head. Copulation being ended, the female, after releasing her genitalia but still gripped by the male's appendages, would then proceed to the business of oviposition. Even to-day, one finds that throughout the whole of the more primitive suborder Zygoptera, the male accompanies the female during oviposition, firmly linked to her prothorax by its anal appendages. After oviposition has persisted for some time, the female frequently copulates again. It will be seen that if she attempted to do this in the primitive manner of curling her abdomen up dorsalwards, she would grope in vain for the male genitalia, since the male's abdomen would be now in a far forward position (fig. 7). Probably after many futile efforts by the female the male would release its grip of her abdomen, and the original method of copulation would be gone through again from the start. I conjecture that there were many such fruitless efforts on the part of the female, hampered by a male reluctant to release its grip, but eventually a time came, when, in her blind groping, she found that by curling her abdomen downwards and forwards in ventri-flexion instead of dorsalwards as usual she was able to consummate the act of copulation (fig. 8). It will be noticed that in tandem-flight (fig. 7) the female has a good view of the male flying above and well forward of her, so that it is possible that sight may have guided her in this change-over from dorsi-flexion to ventri-flexion of the abdomen.

From the time the male took to gripping the female by the base of the abdomen during copulation, it would have gradually abandoned the practice of trying to copulate in the ordinary way, but over a long period it would have been discharging its sperm into the intertergital fossa on the 2nd segment, so that a habit of doing this would have become firmly established, *even when not in copulation*, as is carried out by the dragonfly of to-day. Impatience at not finding a female or at a long wait for one would prompt it to this; sexual perversions are habits probably the most easily acquired and the most difficult to control. Thus before meeting the female, it would have already well primed the genital sac on the 2nd segment, and when at length a female was found, it would attempt to seize her by the base of the abdomen without any preliminary attempt at coitus. This seizure was probably made at the base of the abdomen as that was the normal way prevailing at that epoch, but it would not be too easy, since the fluttering wings of the female would be an obstacle to it. What then would be more natural than that the male should seize upon a more accessible point such as the constriction between the head and thorax of the female offered? (fig. 9). It now only remained for the female to link up by the newly acquired ventral method and the evolution of the modern copulatory process was completed (fig. 10).

Such I believe to have been the line of evolution of the unique method of copulation practised by recent Odonata; each step seems to me to have been the logical outcome of the previous one; each step seems not to have been so much accidental as dictated by necessity and therefore offers the soundest

reasons for arriving at a true interpretation of the path evolution pursued. Whilst other ways and means have been studied, none has proved to be satisfactory, and in the end all have been rejected as either impossible or highly improbable.

Book Notice.

The mosquitoes of Arkansas. By S. J. Carpenter. 8vo. Little Rock (Arkansas State Board of Health) 1939. pp. [iv] + 89, 32 figs. Typewritten and duplicated.

The scope of this book is indicated by its title, but its contents are restricted to the Culicinae.

It gives details of life history and methods of collection and preservation of specimens and guides to their identification.

There is a key to adult female characters and to the fourth stage larvae of the genera dealt with, and this part is succeeded by the description of the species.

There is a chapter devoted to the several matters connected with mosquito control.

Book Notice.

The insect Legion. By M. Burr. pp. xiv + 321, 21 pls., text illust. 8vo. London (Nisbet). (1939.) Price 12*s*. 6*d*.

This book, on which Dr. Burr has been working for some years, is presented in 4 parts. Part 1. Insects themselves; 2. Insects and man; 3. Insects and life; and 4. The history of entomology.

The first part is introductory and comprises a collection of some of the more remarkable facts relating to insects and their lives.

The second is concerned with applied entomology, and is concerned both with noxious and beneficial insects.

The third part deals with the geological age of insects, and the final part with the ancient and modern history of entomology.

The book is an apparent contradiction in that it manages to compress the contents of a quart pot into one designed to hold a pint. There is probably no other book in the English language in which so many interesting statements regarding insects and entomology may be found.

Book Notice.

Medical Entomology with special reference to the health and well-being of man and animals. By W. B. Herms. 3rd edition. 8vo. New York (The Macmillan Co.). 1939. Price 24*s*. pp. xxi + 582, 196 figs.

This work is the third edition of a work which in its earlier editions was known as *Medical and Veterinary Entomology*.

It includes 24 chapters concerning the introduction and scope and method of the work, parasites and parasitism, how insects and arachnids cause and carry disease, their structure and development, details of their structure, and

several chapters devoted to the several orders of insects and related arthropods concerned in medical entomology, and a concluding chapter dealing with the utilisation of arthropods in medical practice.

The method of the work is a progress from the general to the particular, and many of the chapters are prefaced by a full historical summary.

While little space is devoted to taxonomy, sufficient is included to enable the reader to determine nearly related insects likely to be confused. The volume is well illustrated and many of the illustrations are original.

In the case of diseases transmitted by insects, the symptoms are described in more or less detail.

There is a full index and each chapter is given a special bibliography.

Book Notice.

The Social Life of Animals. By W. C. Allee. 8vo. London (Heinemann). (1939.) pp. xiv + 265, 5 pls., 49 figs. Price 12*s.* 6*d.*

The author of this book is Professor of Zoology at the University of Chicago, and for over thirty years he has worked on the group behaviour of animals.

The book comprises eight chapters: Science versus metaphysics, History and natural history, Beginnings of co-operation, Aggregations of higher animals, Group behaviour, Group organisation, Some human implications, Social transitions.

The book is the result of an invitation to deliver the Norman Wait Harris lectures at North-Western University, and is written in an easy style suitable to the non-specialist.

There is a select list of literature cited and an index.

No date of publication can be found in the book.

Book Notice.

The World of Insects. By C. D. Duncan and G. Pickwell. 8vo. London (McGraw Hill). 1939. pp. x + 409, 1 pl. col., 193 figs. Price 21*s.*

The nineteen chapters of this book attempt to give a general view of the world of insects with comparative brevity and definition of all technical words. Notice is taken of the many subjects on which insects force their attentions.

The book deals with structure, growth of insects, feeding and reproductive habits, breathing movement and protection, insect noises, the orders of insects, social life and beneficial and noxious insects and their control, collecting, rearing and preserving insects.

Throughout, stress is laid rather on the living insect than on the museum specimen. The book is profusely illustrated and has a short selected list of references to literature arranged under subjects, and an index.

SOME BUTTERFLY MIGRATIONS IN EUROPE, ASIA AND AUSTRALIA

By C. B. Williams, Sc.D., F.R.E.S.

(*Rothamsted Experimental Station, Harpenden.*)

The following migrations are dealt with below.

Europe.

1–3. *Vanessa cardui* (L.) in Greece, Corsica and France.
4. *Vanessa cardui* (L.), *io* (L.) and *atalanta* (L.) in France.
5. *Pieris brassicae* (L.) in the Austrian Tyrol.
6. *Colias croceus* (Fabr.) in the Pyrénées.
7. *Plusia gamma* (L.) on Mont Blanc.

Asia.

8–9. Catopsilias in Java and India.
10. *Zegris eupheme* (Esp.) in Iraq.
11. *Vanessa cardui* (L.) in Arabia.
12. *Lampides boeticus* (L.) in India.
13. *Ypthima bolanica* Marshall in India.
14. *Appias paulina* (Cram.) in Ceylon.

Australia.

15. *Vanessa cardui* (L.) and other insects off S. Australia.

(1) *Vanessa cardui* (L.) in Greece in 1917.

Prof. Dr. C. A. Isaakides wrote that there was an invasion of *V. cardui* in the neighbourhood of Athens in 1917.

In April of that year the market gardens at Haghios Joannis Rentes and the fields in the vicinity were covered with caterpillars of this butterfly. Their number was very great and the artichokes were eaten until only worthless stumps remained. All the dairies in Athens were affected, since artichokes are cultivated there to supply food to milch cows.

The caterpillars came from south to north and they covered an area of at least five kilometres square, which they made black, as also the walls of houses and factories which they marched over.

At the same period larvae of *V. cardui* also invaded uncultivated fields to the north of Athens.

Prof. Isaakides saw no trace of larvae of the second generation.

(2) *Vanessa cardui* (L.) in Corsica in 1926.

Mr. B. C. S. Warren has kindly given me the following account of his observations.

"Flight observed between 17 July & (?) end of month, 1926, at Vizzavona, Corsica.

"During the period, varying numbers of *V. cardui* passed along the railway line between Tattone and Vizzavona, flying due south, usually some 8–10 feet above the ground. On coming to the Vizzavona railway station where

the line enters a long tunnel under the Col de Vizzavona, the butterflies turned up the mountain-side, flying high over the tree tops, but keeping the same direction. The weather was a little uncertain: some days without wind, some days with a strong wind from the south. The flight did not seem affected by the changes.

"By the light of a garden lamp outside the Grand Hotel near Vizzavona station, individuals of *V. cardui* were seen still flying past up over the forest long after dark on several evenings.

"On one day the flight was observed to be in the reverse direction; *i.e.* from south to north, down the railway line towards Tattone, but the next day the southward flight had been resumed."

(3) *Vanessa cardui* (L.) in France in 1932.

Monsieur René Gastineau wrote to say that one day towards the end of June 1932 he saw a definite flight of *Vanessa cardui* at Ballancourt (Seine-et-Oise), about 35 km. south of Paris. He first noticed the flight about 10 a.m. and it lasted until about 1.30 p.m. Many thousands of butterflies were seen. At first they were flying singly but the numbers increased rapidly and reached a maximum about 12.30 p.m. After this the numbers diminished. They were flying at the level of the tree tops and the roofs of the houses, and at a speed of not less than 10 km.p.h. (6–7 m.p.h.). They kept steadily to their directions from south-south-west to north-north-east. All seemed to follow the same line, and the width of the largest group in the flight was not more than 15 metres. The flight did not appear dense even when one saw more than 50 butterflies in a cubic metre. When less numerous, individuals passed at exactly the same spot with "striking prevision." The weather was fine, a little dull, with some cloud, no wind and no movement of the trees.

(4) Flight of *Vanessa cardui* (L.), *V. atalanta* (L.) and *V. io* (L.) in France.

Mme. Jeanne Leclerc has kindly given me the following information about a flight of butterflies she saw near Lyon in July 1937.

The locality was situated about 7 km. south of Lyon and 3 km. from the course of the River Rhone, on the foothills of the Cevennes at an altitude of about 250 m. (800 ft.), and open in all directions except to the west. The slopes of the hills are covered with weedy vegetation, and with fruit trees, vines, etc. This route is followed by migratory passerine birds in preference to the Rhone Valley itself. The situation is a good one for butterflies, which are always present in large numbers.

On 8th July 1937 the weather was fine, clear, with a very light north-north-west wind about 2 metres per sec. and maximum temperature about 36° C. (96° F.). Unusual numbers of butterflies were noted at 10 a.m. flying from south to north in groups of 2 or 3, two metres from the ground on an average, never higher than 5 metres. They were abnormally lively, hardly resting for a few seconds on Buddleias, where other species were gorging themselves. The majority were *Vanessa cardui* accompanied by about 20% *V. io* and about 5% *V. atalanta*. Individuals of other species joined them, but only followed for a short time, dropping out to feed on the Buddleias. It was difficult to estimate their numbers, but at one time 30–40 were counted on a Buddleia, then there was a gap of 10–15 minutes. Probably 100 in 20 minutes was the average number crossing a wall 15 metres long. The speed of flight was estimated at between 6 and 9 km. per hour (4–6 m.p.h.). The flight continued until sunset, after which none was seen.

On 9th July the weather was fine with some cirrus cloud; maximum temperature 36° C.; wind light north-west veering to west during the day and getting stronger towards evening. During the afternoon cumulus clouds occurred in the south-west and there was a storm on Mt. Pilat and in the Rhone Valley about 50 km. to the south.

Numerous butterflies passed between 10 a.m. and 4 p.m., as many as 50 at a time being seen on the Buddleias.

On 10th July, fine, light clouds; brisk north wind (4–5 m. per sec.); maximum temperature 29° C. (86° F.), there were much fewer butterflies : almost all *V. io*. A few *cardui* passed flying higher (3–9 m.), flying against the wind but with numerous zigzags. All captured had torn wings. None was seen after sunset.

11th July. Feeble north wind. Proportion of species inverted; practically no *V. io*. Not many passed, only 4–5 at a time on the Buddleias instead of 50.

12th July. Cloudy, max. temp. 26° C. (79° F.). Short showers. Rain in the south, no butterflies seen—nor on the following days.

Mme. Leclerc sent specimens as follows :—

Caught on 9th July—*V. cardui* : 3 males, 1 female; *V. atalanta* : 1 female; *V. io* : 1 male, 1 female.

Caught on 10th July—*V. io* : 1 female, 5 males.

Caught on 11th July—*V. cardui* : 1 male, 1 female; *V. urticae* : 1 male.

The above record is of special interest as it is the first account of a definite movement of *Vanessa io*, and it is also the first account of a mixed movement of *V. cardui*, *V. atalanta* and *V. io*.

V. io has only recently been considered as a possible migrant, as it has occurred on several occasions on lightships off the British coast, and has been recorded coming in from the sea off our Norfolk coast. The above record indicates that the species must be considered capable of quite definite mass movements.

(5) *Pieris brassicae* (L.) in the Tyrol.

Mr. T. W. Kirkpatrick kindly gave me the following notes on a migration of white butterflies that he saw on 24th July 1937, on the Grossglockner Mt., in north-west Carinthia, Austrian Tyrol.

" This morning, cloudless, warm, slight south-west wind, I came over from Rudolfshütte (2250 m.) to Moserboden. I first noticed a few of the butterflies at the top of the pass (Kapruner Törl, 2630 m.), flying west, about 9.30 a.m. A little lower down, toward Moserboden, between 10.00 and noon, there were thousands of them, flying up the valley, more or less against the slight wind. This is the most ' determined ' migration I have seen outside Africa, *i.e.* they were not stopping at all, even when there were lots of flowers. I sat on a rock for some time, and between me and another rock 10 yards away they were passing at between 5 and 10 per second; they were all across the valley (200–300 yards wide), but not I think so thick on the other side. At Moserboden (1960 m.) it began to cloud over about 12.30 p.m. Thousands of butterflies were about, but the migration was less determined, many stopping. I started to come up to this hut [Heinrich Schwaiger Hütte] about 2.30 p.m.; still a lot about, but the general—not very determined—movement was *down* the valley, towards the north. There was no wind, with thunderstorms approaching from south-west, north-west, and north. At about 4 p.m. and 2700 m. a heavy thunderstorm began and I saw no more.

"I had noticed a lot of *brassicae* about during the past few days, but no migration."

On the following day (25th July) Mr. Kirkpatrick noticed many dead *P. brassicae* on the snow up to at least 3300 m. (10,800 ft.) on the Gr. Wiesbach Horn (peak about 3550 m.). Also particularly in one place quite near the top—say 3400 m.—lots of what he is almost positive were *Nomophila noctuella*, all apparently dead. In some places there were 5 or 6 or more per square yard, and they must have averaged 1 per square yard. Lower down, below 3000 metres (9800 ft.), none was seen.

P. brassicae was still quite common in the valley between Moserboden and Kesselfalls during the afternoon of the 25th, but no noticeable migration. Later that night there was a very heavy thunderstorm. All the bridges on the path were destroyed and the roads blocked with earth and trees.

(6) *Colias edusa* (Fabr.) (*croceus*) in the Pyrénées.

M. René Oberthur wrote to me on 4th July 1936 from Vernet-les-Bains, Pyrénées-Orientales, France, as follows :—

"In very fine weather, *Colias edusa* have flown past all the morning and up to 3 p.m. singly but altogether a large number and all in the same direction, towards the north, with the flight, as usual, very rapid.

"The *Colias* appear to be newly emerged and are coming doubtless from Spain or from north Africa.

"On the following day [5th July] the flight was continuing at 9 a.m. in the same direction and fast as usual in fine weather.

"The butterflies were flying about 2 metres above the ground; practically no wind, but what little there was came from the north."

In a map which M. Oberthur sent the direction of flight was shown as slightly to the east of north.

(7) Moths (? *Plusia gamma* (L.)) at the summit of Mont Blanc.

Mr. Harold Dole informed me that on the 6th September 1922 when on the very summit of Mont Blanc he found several dark brown moths half buried in the snow, and on the way down he saw more on the ridge between the summit and the Bosses du Dromedaire (14,885 feet).

The moths were about $1\frac{1}{2}$ to 2 inches across the wing.

The previous day the wind had been westerly and fresh snow must have fallen on the summit. During the night of the 5th–6th a strong wind developed from the north. The wind ceased suddenly just over the summit where the moths were found.

Mr. Dole noted that the snow on the summit of Mont Blanc is continually building up so that perhaps the moths that he saw are there still beneath the snow. The observatory at the summit was last seen in 1909 and is now under 20 or 30 feet of snow !

After he received a letter from me on the above subject, Mr. Dole went to the British Museum (Natural History) in South Kensington and looked through the exhibited collection. He came to the conclusion that the moth must have been *Plusia gamma*, the Silver Y. He wrote : "Certainly nothing else there had so close a resemblance. The moths I found certainly had the distinct light mark on the upper wings and the lower wings had that paler brown near

the body. The only respect in which I remember any difference at all is that they had slightly less brilliant colour. I distinctly remember the marking of the upper wings giving the impression of being double owing to the parallel streak below the upper edge and above the white mark."

Mr. Dole thinks that the moths must have been blown up from the Chamonix Valley over the Taconnaz and Bossons Glaciers on to the Plateau between the Dome de Goûter and the Vallot Refuge and thence to the summit.

(8) *Catopsilia crocale* (Cram.) in Java in 1938.

Mr. G. H. Glish gave me the following account of a migration that he saw in the Bodjongno District, Rembany, east Java, in the valley of the Solo River. This is a valley about 60 miles wide and bounded on the north and south by Teak forest hills.

About the middle of September 1938 he noticed a distinct migration of yellow butterflies moving from west to due east over a 50–60 mile front. It was definite on the 20th September and was still in progress on the 12th October, when he wrote. It was most noticeable between 10 a.m. and 3 p.m. every day. The wind from the 4th October was easterly, with thunderstorms which stopped the flights. The insects were flying at from 10 to 20 feet above the ground, and were passing singly or in twos. At one time (10.x.38) over a 30-yard front he counted 500 pass in one hour.

The speed of flight (tested against a motor car) was between 12 and 14 km. per hour (8–9 m.p.h.).

Mr. Glish sent 4 specimens, all of which were *Catopsilia crocale* (Cram.), 3 males and one female.

I have had no recent record of butterfly migration for Java, but as long ago as 1891 Piepers (*Naturk. Tijdsch. Ned.-Ind.* **50** (2) : 198) gave an account of a number of movements that he had seen there, and it is interesting to note that the flights were by the same species, at the same time of year, and mostly in an easterly direction.

(9) *Catopsilia crocale* (Cram.) and *C. pomona* (Fabr.) in India.

Mr. R. C. Busher gave me the following record of a flight seen in the Naini Tal district, U.P., India.

" Only occasionally did I see flights of Catopsilias. I have a definite record of a very extensive flight which took place on the 11th August 1935, between 10 a.m. and noon during a short spell of fine weather during the rains. This flight was much more directional than that of *L. boeticus* and the butterflies streamed by like a river, about 100 yards wide, at this particular spot. The swarm consisted of *C. crocale* and *C. pomona* var. *catilla* (Cram.). The females with reddish-purple blotches on the underside predominated. The two species seemed to be in equal proportions. There were also a few *C. florella* (Fabr.). Their direction was also south to north. Unlike *L. boeticus* they rarely settled during the flight."

(10) *Zegris eupheme* (Esp.) in Iraq.

Lt.-Col. H. D. Peile informed me that he saw *Zegris eupheme* subsp. *dyala* Peile migrating in large numbers towards the south-west against the wind at Kizil Robat, R. Diyala, Iraq, from 11th to 14th March 1919. He added that on some days dozens passed in a minute.

This is the first record of this species as a migrant.

(11) *V. cardui* (L.) in Arabia in 1937.

Mr. R. C. Maxwell Darling kindly sent me the following record.

The locality was the Trucial Coast of Arabia. The Painted Lady (*Vanessa cardui*) was very common all over the coast, and on 20th February 1937, when he drove some distance east from Sharja, they were very abundant and all flying slowly along the coast roughly in a north-easterly direction. This was near the end of the rainy season and the rains had been exceptionally good. The butterflies were flying by thousands mostly within eight feet of the ground. There was no definite wind so far as he can remember. The butterflies were seen flying from about 18th February to end of March, but this was the only occasion in which they were present in numbers or migrating. There had been exceptionally good rains on the Trucial Coast during that season and the vegetation was at its best.

(12) *Lampides boeticus* (L.) in India.

Mr. R. C. Busher gives me the following information for the region round Naini Tal, U.P.

" During the past 20 years or so I have noted flights of *Lampides boeticus* about the middle of September, *i.e.* after the end of the Monsoon rains. The direction was invariably south to north. They would come up from the lower hills (alt. 3000–5000 ft.) flying round in circles, occasionally settling, but maintaining a rhythmic movement towards the north. They flew over the higher hills (7500–8500 ft.) and eventually scattered when they reached the maze of valleys between Naini Tal and the snow-capped mountains."

(13) *Ypthima bolanica* Marshall (Satyridae) in Waziristan.

Lt.-Col. H. D. Peile informed me that at Dredoni, about 3 miles from Miramshah in the Tochi Valley (foothills) in north Waziristan, on 8th–9th September 1917 he captured 41 males and 16 females of *Y. bolanica* in fresh condition " which were migrating against the wind from east to west and easy to catch."

Records of migration in the Satyridae are very few.

(14) *Appias paulina* (Cram.) in Ceylon.

Dr. S. H. Jayewickreme of Kandy, Ceylon, kindly sent me the following record accompanied by 9 males and 6 females of *Appias paulina*.

" *Time of flight*—approx. between 12 noon and 3 p.m. Number of specimens caught—17 (9 males, 6 females). Efforts at pairing not noticed. Direction of flight—east to west. Flight observed in garden and took place in two lines alongside flower beds on either side of the lawn. Total number during the three hours could not have exceeded 500. Maximum height of flight—about 10 feet. Minimum—about 2 feet. Butterflies generally came right up against the side of the house, which is about 15 feet in height, and then scaled over. Some appeared to notice the house before coming to it and went over when about 2 feet away from it.

Date	Temp.		Baro. P. (corr. to temp.)		Humidity	
	Max.	Min.	Max.	Min.	at 9.30 a.m.	at 3.30 p.m.
20.xi.38	84·5	63·5	28·312	28·183	76	53
21.xi.38	84·6	66·1	28·291	28·169	70	58
22.xi.38	80·0	68·5	28·273	28·179	78	70

(Meteorological data supplied by the Superintendent, Colombo Observatory. Direction of the wind not recorded at Kandy.)

" During time of flight there was no appreciable wind. Observatory notes that direction of the wind over the island generally was as follows: 20th, north-north-east; 21st, north; 22nd, north.

" *Remarks.* North-east monsoon long delayed following a very poor south-west monsoon. At the time of the flight drought conditions were prevailing over a large part of the island. The flight took place in a rather scattered manner and it was difficult to capture more than 17 specimens. On the 20th and the 22nd flights also took place at about the same time but the numbers were very few and no specimens were taken. The numbers on the 22nd much fewer than on the 20th."

(15) Mixed flight of Butterflies and other Insects in Australia.

Mr. H. B. Hardy sent the following interesting record.

" When towing barges at Port Pirie, S. Australia, in the early morning of 12th March 1939, moths were fairly common all night. From midnight to 6 a.m. the air was full of insects, and for 5–10 minutes between about 4.30 and 4.45 a.m. the insects were dense enough to affect visibility in a manner similar to a snowstorm. The insects were flying almost due north.

" Mr. Hardy captured six specimens, which included two butterflies, two moths, and one grasshopper as follows :—

1 *Vanessa cardui kershawi* McCoy ♀.
1 *Precis villida* Fab. ♂.
1 *Loxostege affinitatis* Led.
1 *Neocleptria punctifera* Walk.
1 *Chorthoicetes terminifera* Walk.

The exact position was, according to Mr. Hardy, between beacons 4 and 5 marking the Port Pirie Channel which is at that point about 3 miles wide. The weather was clear, the sea calm, air temperature about 70° F. Sunrise was at about 6.15 a.m."

Book Notice.

Faunistischer Führer durch die Coleopteren-Literatur. Von S. Schenkling. Band 1. Lieferung 5. Europa. pp. 257–320. Neubrandenburg (Verlag G. Feller). 1939. Price Rmk. 6.00.

Herr Schenkling's great work on the literature of the Coleoptera is continued by the appearance of Lieferung 5, which lists the literature on the beetles of Switzerland and the commencement of that relating to Germany. The 20th chapter is therefore now opened. The part completes the literature relating to Germany as a whole and that of north Germany and the first part of that relating to central Germany.

The arrangement follows that used in earlier parts.

SOME RECORDS OF BUTTERFLY MIGRATION IN AMERICA

By C. B. Williams, Sc.D., F.R.E.S.

(*Rothamsted Experimental Station, Harpenden.*)

The following flights are dealt with below.

1. *Acolastus amyntas* (Fabr.) in Brazil.
2. *Eunica monima* (Cram.) in Mexico.
3. *Lignyostola crinisus* (Cram.) in British Guiana.
4. *Gonepteryx clorinde* (Godart) and others in Mexico.
5. *Coea acheronta* (Fabr.) in British Guiana.

6–8. Catopsilias in British Guiana, in the Caribbean Sea and in the Bahamas Islands.

9. White Butterflies in the Argentine.

10–11. *Urania fulgens* (Walk.) in Costa Rica and Mexico.

12. *Urania leilus* L. in Brazil.
13. *Vanessa cardui* (L.) in the southwest U.S.A.

(1) *Acolastus amyntas* (Fabr.) in Brazil.

In my book 1930, *Migration of Butterflies* : 254, I referred to the fact that Seitz had seen a migration of the Skipper butterfly *A. amyntas* in Brazil, but that no details had been obtained.

Through the kindness of Dr. Elie Franz I can now quote the following account sent to her by Dr. Martin, who was with Dr. Seitz at the time.

" The observations on this migration were made about the 10th January 1927 at Itatiaya, about 100 miles west of Rio Janeiro, Brazil. We were at a height of 800–900 metres. The butterflies flew not as a compact body but singly in a continuous stream so that without any breaks in time a few were always flying by. The flight lasted several days. It should be noted that the insects were almost entirely in a fresh condition—*i.e.* had hatched not long before the flight. Before and after this migration the species were to be met with everywhere in the mountains. The flight moved approximately from S. to N. During the flight several isolated flowering trees were sought by numerous individuals for feeding purposes, so that by shaking the tree hundreds of individuals flew off. After completing feeding they flew off further in the prescribed direction."

(2) *Eunica monima* (Cram.) in Mexico.

Mr. D. B. Leglers sent me the following account of a migration of *Eunica monima* that he observed in the village of Xocemplich, in the east-central portion of the Yucatan peninsula, Mexico.

" The enclosed specimen is one of a migration that I first noticed on the afternoon of 20th May 1939. They came from the south-east, the majority just over the tops of the trees, though some were possibly 100 or more feet in the air. On either hand the flight was as far as it was possible to see. They did not come in clouds but I would say at a guess that fully 100 passed over one square yard every minute. For the next eight days the procession con-

tinued, shifting to the west on the second afternoon (the 21st). The migration started up about noon and continued till near dark. No matter what direction the wind, there was always a definite heading into the west. One morning I walked some distance into the woods and found myriads swarming around in the trees or resting on the leaves. The flight was suddenly brought to an end by heavy rain on the 30th May.

"The Indians here say that this is a common occurrence and that the butterflies hatch out in the jungle with the first rains of the rainy season."

A specimen was sent.

(3) *Lignyostola crinisus* (Cram.) in British Guiana.

Mr. D. Fanshawe kindly sent me the following account of a migration which he observed.

"From 15th February to 8th March 1939 small brown butterflies with the curiously jerky flight of the Hesperiid were migrating in a south-east direction across the Penal Settlement—now the Forest Station—and the Mazaruni River, British Guiana. Specimens taken were identified by the Government Entomologist, L. D. Cleare, as *Lignyostola crinisus* (Cram.). The width of the flight was approximately 4 miles, from the neighbourhood of Swarte Hoek on the Essequibo River up to Palmer's Point on the Mazaruni River.

"Migration nearly always took place during the afternoons from midday or even 11 a.m. onwards till about 3 p.m. as long as it was not actually raining, but whether it was sunny or overcast appeared to make no difference as migration was noted on both dull and sunny afternoons. The wind was always from the north-east varying from strength 2–3 at midday to 4–5 during the afternoons, and I have the impression that the stronger the breeze, the greater the migration numerically, although I cannot verify this.

"Migration was in two waves, separated by a spell of 6 days of wet weather, from the 15th to 23rd with a peak on the 15th, the numbers decreasing gradually till the 23rd, followed by a minor peak on the 2nd, decreasing till 8th March, when migration ceased.

"The numbers at the major peak on the 15th February gave the impression of a light snowstorm but a count was not taken and the numbers were approximately the same over the whole width of flight, as I travelled along the stretch of river in question on that day. The height of the flight over the water was from 8 to 15 feet."

(4) *Gonepteryx clorinde* (Godart) and other butterflies in Mexico in 1933.

Mr. C. W. Sabrosky has kindly given me the following notes on flights of butterflies that he observed in Mexico in 1933. The specimens were identified by the Field Museum of Chicago.

On 28th July 1933 he was collecting near the village of Tamos, 8 miles west of Tampico, Mexico, on the north bank of the Rio Panuco. Many butterflies were migrating in a north-east direction, flying into the wind, including a large white one with orange spots on each fore-wing (*Gonepteryx clorinde* (Godt.) and brilliant blue striped ones. Three specimens of the latter were captured and were all different species of the genus *Myscelia*; *M. cyaniris* Dbl., *M. ethusa* (Bsd.) and *M. rogenhoferi* Fldr.

There was a continual procession of the butterflies from 11.30 a.m. to 5 p.m., when he left the locality.

On 29th July he was at Tamos until noon but there was constant rain and no butterflies seen.

On 30th July none was seen 3 miles north of Tampico.

On 31st July he took a train along the south bank of Rio Panuco to about 15 miles inland but no flight was seen.

On 1st and 2nd August no observations were made.

On 3rd August he went by train to Guerrero, about 63 miles inland (west) from Tampico in the State of San Luis Potosi. Here a large butterfly migration was observed almost entirely of Pierids and especially *Gonepteryx clorinde* and "Sulphurs." All were flying rapidly in a southerly direction, apparently not alighting. They were observed from 10 to 11 a.m., when he left the locality.

Specimens of "Sulphurs" captured on this date were identified as *Gonepteryx maerula* ♀ form *gueneeana* (Bsd.) and *Catopsilia eubule* (L.).

On 4th August butterflies were again seen migrating at Tamos, mainly the large Pierid (*G. clorinde*). They were seen at 10 a.m. and were still flying steadily at 2 p.m. On this day they were flying to the south across the Rio Panuco.

On 5th August no observations were taken as he was preparing to leave the district.

(5) *Coea acheronta* (Fabr.) in British Guiana.

Dr. J. G. Myers kindly gave me the following record :—

On the 10th November 1935, on the Southern Savannahs of the Rupununi, British Guiana, near Isherton, he noted in his diary "Ever since we left Wichabai (some sixty miles, all across Savannahs) I have been intrigued by a dark butterfly, singly, every few hundred yards, flying steadily across the track diagonally, always in the same direction, very strongly, very swift (I had several unsuccessful sprints !) dodging net, unwavering, apparently not interested in anything in the Savannah. José finally caught two. Direction of flight always about south-east by east. Prevailing wind strong during the whole day north-east. Sometimes single pale yellow or almost white pierids taking the same course. The journey from Wichabai to Isherton took four days."

The butterfly was determined as *Coea acheronta* by the Imperial Institute of Entomology.

(6) Catopsilias in British Guiana in 1919.

Dr. Percy Rendall allows me to record that about the 19th July 1912 he saw a great flight of yellow butterflies when he was canoeing on the Potaro River, British Guiana, between Tumatamari falls and Kaieteur falls.

The flight consisted of hundreds of thousands of yellow butterflies all flying "down the river." The river Potaro at this point runs in general from west to east, but it is somewhat winding so that the direction of flight cannot be settled definitely.

(7) *Catopsilia eubule* (L.) in the Caribbean Sea.

Mr. Eugene Murray-Aaron kindly sent me the following record from his notebook.

"1891, Franz Herzog, Entomologist from Frankfurt-am-Main, returning from inspection of Panama Canal work under De Lesseps, tells me of 'large numbers of *Callidryas eubule* flying towards the south about 100 miles south

of Jamaica.' Some of them, apparently exhausted, landed on the ship's deck, several of which in papers he showed me. The identification was correct. He added that the ship's captain reported them as 'a common thing about hurricane time; sometimes they are all white.' Hurricane time is between mid-August and mid-October in those waters."

The above record is of special interest as records of insect migration in the Caribbean Sea are very few, although one would expect many such flights to take place.

(8) *Catopsilia eubule* (L.) at sea in the Bahamas.

Mr. E. Murray-Aaron informed me that on the 12th or 13th October 1889 when he was on his way from New York to Jamaica he passed through quite definite flights of *Catopsilia eubule* in the neighbourhood of the Fortune Island Passage in the Bahamas. They were flying to the south-east in parallel columns and many hundreds were in sight at once.

A popular account of this, but without exact dates, was published in Mr. Murray-Aaron's 1894, *Butterfly Hunters in the Caribbees* : 99–100.

(9) White Butterflies in the Argentine.

Miss R. St. John wrote that some years ago she saw a migration of white butterflies at Carcarana about 30 miles west of Rosario de Santa Fé, Argentina (about 300 miles up the river from Buenos Aires). The day was one in the autumn (March, April and May) and the flight was direct from north to south and took quite a quarter of an hour to go over. While it lasted it was like a broad and deep white cloud. The butterfly "was the ordinary creamy white one that one always sees about in the Argentina."

A sudden abundance of white butterflies was also noted about the same time by another observer about 100 miles to the south, but no definite movement was seen.

The white butterfly *Ascia monuste* (L.) (= *phileta*) is common in Argentina and has several times been recorded migrating there by Hayward, so that the species referred to above is probably this. Hayward's records, though at the same time of the year, were in the opposite direction, towards the north.

(10) *Urania fulgens* (Walk.) in Costa Rica.

Mr. A. F. Skutch wrote that he had seen migrations of the day-flying moth *Urania fulgens* at Vara Blanca in Costa Rica as follows :—

"I first began to notice the migrations of this moth in April 1938, when practically all that I saw were flying northward, headed down the slope of the Cordillera, the axis of which lies east and west, towards the vast forested lowland plains of northern Costa Rica and eastern Nicaragua. The vicinity at which I observed them was at an altitude in the neighbourhood of 5500 feet, a region of scattered clearings in heavy rain-forest. Their flight was strong, swift and only slightly wavering, and deviated little from the north. When crossing the open pastures, they sometimes flew very low, but at other times they would be as high as the tops of the tall trees. They always travelled singly, but sometimes several would be in sight at once. As before mentioned, I never saw them pause to rest or seek nourishment.

"Through April and May, I daily saw these conspicuous moths winging northward past my house. Then, about the beginning of June, I began to notice that some were flying southward. Soon the great majority were

journeying southward, a course which would take them across the continental divide and, if continued, down on to the Central Plateau. During June, July and early August the southward drift continued, and on some days I saw considerable numbers pass in this direction. Still, a minority continued to move northward; and more rarely I beheld one whose course diverged considerably from the north-and-south line."

Vara Blanca is on the northern slope of the central Cordilleras.

This record is of particular interest as it is a further confirmation of the double season of migration for *U. fulgens* in this part of the world, which I have already discussed (Williams, 1937, *Proc. R. ent. Soc. Lond.* (A) **12** : 141–147), and also confirms the reversal of direction of flight which has been recorded by some observers and disputed by others.

(11) *Urania fulgens* (Walk.) in Mexico.

Mr. W. Schaus wrote (3.ix.1937) as follows :—

" I collected for several years in Mexico mostly on the eastern slope and naturally observed the swarms of *Urania* always flying in a north-westerly direction. The flight was chiefly in the middle of the day and in the afternoon. Once I went down to Vera Cruz on a collecting trip and was surprised to find at night a number of *Urania* on the walls below the electric light on the south-east corners of the buildings. It was a surprise and I naturally wondered if they were on a return journey."

(12) *Urania leilus* L. in Brazil.

Miss M. E. Fountaine informed me that on 22nd January 1930 at about 4 p.m. she saw a continuous flight of *Urania* sp., probably *leilus*, flying from north to south across the Delta of the Amazon between that river and the Para River. The water was very rough and numbers were engulfed by the waves.

(13) *Vanessa cardui* (L.) in California, Arizona and New Mexico in March and April 1939.

Mr. P. R. Gleason wrote (24th March 1939) as follows :—

" The first migration noted was on 17th March [1939] in the desert between Indio, California, and Blythe, which is on the Californian bank of the Colorado River. This desert is usually referred to as the ' Colorado Desert.' Indio is about 400 feet below sea level and we had travelled about 40 miles coming up to the level of the river. We saw the first butterflies about 4 p.m. and the last of the flight shortly before we reached Blythe, so the distance across the path of flight, at an angle of 45° to its direction, was about 60 miles. Most of the insects were flying in a north-west direction, though a few crossed the highway in a southerly direction. The car speed was about 60 m.p.h. and we saw about 15 butterflies per minute. This would mean about 15 individuals crossing a stretch a mile wide at any one second or 900 crossing a line diagonally the entire path of the flight at any one time. The speed of the flight could not have been more than 4 miles per hour and the insects were at no place more than 2 feet above the ground level. Several hundred thousand butterflies must have been concerned in the flight. The day was bright and quite hot with almost no wind. The area covered is usually severely parched with a minimum of desert plants. This year, however, considerable

rain has fallen in the desert, so that it was covered with short grass and quite a few roadside flowers were in bloom.

" The following morning we crossed western Arizona to Phoenix but saw no butterflies at all, perhaps because of the overcast weather.

" Again on the 20th March we ran into a migration of *V. cardui.* This time they were crossing the high ranges between Superior and Globe, Arizona, flying quite definitely westward and about 4–5 feet above the ground. I should say at a guess that one or more would strike our windshield every few seconds and that we were averaging only a little more than 30 m.p.h. on account of the stiff grades and sharp curves of the highway. This day was partly cloudy and at the elevation of the mountain passes (5000 feet) the air was quite cold. The butterflies were passing through every visible ravine and gulch along the right of way and we did not run out of them until we had come down into Miami, a distance of 20 miles from the point where we first observed them. Among the *cardui* were a few white Pierids which may or may not have been migrating. By the time we reached Lordsburg it was raining heavily and when we reached Silver City on the following day we found that there had been a freak hailstorm which had piled up large drifts of consolidated ice."

Mr. Gleason witnessed a third movement of *V. cardui* near Silver City in the south-west of New Mexico, on the 20th April 1939, which he describes as follows :—

" This morning about 11 a.m. we drove from Silver City to Cherry Creek, to reach which we must cross the main Continental divide at a town called Pinos Altos, some 8 miles from Silver City. The divide is here at an altitude of about 7000 feet and Cherry Creek lies about 6 miles west of Pinos Altos at the bottom of a deep rugged canyon.

" About a mile out of Silver City we began to see butterflies flying quite definitely in a south-easterly direction. They were few in number and so scattered that none could be caught. We saw them all the way to Pinos Altos on a front of not less than 5 miles. There were a few on the west side though here the pines grew so densely that the flight seemed to be more or less broken. Once we had dropped into the canyon (which runs more or less from north to south) we saw no more.

" On the way home we noted a large swarm of the same butterflies about 3 miles west of Pinos Altos at about 3.30 p.m. They were fairly whizzing by, at nearly 20 m.p.h., I should guess, but I managed to net one specimen.

" For some minutes they passed by at the rate of about 5 butterflies per second with brief little intervals between successive groups. I should say from 50 to 100 would be the average passing per minute. By 4 p.m. the flight came to a sudden conclusion. Only a few stragglers were visible after this hour, though odd specimens were seen flying to the east all the way to Silver City.

" The day was warm, only partly clouded, with a light breeze, say 5 miles an hour, blowing out of the south-east. The direction of the flight was slightly south of east and very definite. The height of the flight above the ground was from 2 to 4 feet.

" The specimen captured was *V. cardui.*"

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